

*BLOCKING A SELECTIVE ASSOCIATION  
IN PIGEONS*

STANLEY J. WEISS AND LEIGH V. PANLILIO

AMERICAN UNIVERSITY AND  
NATIONAL INSTITUTE ON DRUG ABUSE

Experiment 1 demonstrated for the first time a stimulus–reinforcer interaction in pigeons trained with free-operant multiple schedules of reinforcement. Pigeons that treadle pressed in the presence of a tone-light (TL) compound for food exhibited primarily visual stimulus control on a stimulus–element test, whereas pigeons that avoided shock in TL exhibited auditory control. In Experiment 2, this selective association was blocked in pigeons pretrained with the biologically contingency-disadvantaged element of the compound (i.e., tone-food or light-shock) before TL training. When this pretraining preceded compound-stimulus training, control was now auditory in pigeons that treadle pressed for food and was visual in pigeons that avoided shock. Previous attempts at blocking this selective association were unsuccessful in pigeons (LoLordo, Jacobs, & Foree, 1982) but were successful in rats (Schindler & Weiss, 1985). Experiment 2 established that selective associations can be blocked in pigeons when the procedures that were effective with rats were systematically replicated. These results further demonstrate the cross-species generality of an associative attentional mechanism involving a biological constraint on learning in species with different dominant sensory systems.

*Key words:* selective associations, blocking, stimulus–reinforcer interaction, biological constraints on learning, species comparisons, treadle press, pigeons

Studies of constraints on learning have demonstrated that contingency factors interact with the physical characteristics of stimuli to influence stimulus salience. Selective associations are demonstrated when a set of stimuli has been given equal opportunity to control a response, but the reinforcement contingencies determine which stimulus is most effective. To reveal a selective association, training is typically conducted with a compound stimulus. Then, the elements of the compound are presented separately in testing to determine the degree to which each element has gained control of the response. When a tone-plus-light (TL) compound discriminative stimulus ( $S^D$ ) occasioned pigeons' (Foree & LoLordo, 1973) or rats' (Schindler & Weiss, 1982) operant responding, food-maintained responding came under visual control, whereas auditory control increased when responding was maintained by shock avoidance. This type of selective association has been described as a *stimulus–reinforcer interaction* (LoLordo, 1979).

Although these selective associations were believed to be “hard-wired” constraints on learning, there is evidence that they are modifiable. Schindler and Weiss (1985) blocked (Kamin, 1969) a stimulus–reinforcer interaction in rats by bringing lever pressing under control of the biologically contingency-disadvantaged element of the compound stimulus prior to compound-stimulus training. Food-group rats initially bar pressed for food in the presence of a tone, while food was unavailable (extinction) in the absence of the tone. After this discrimination was firmly established, a light was added to the tone, creating a TL compound  $S^D$ , for 15 additional training sessions. Symmetrically, rats in the avoidance group were pretrained to avoid shock during a light, while the absence of light was shock free (extinction). Then, a tone was added to the light, creating a TL compound  $S^D$ , and training continued for 15 additional sessions.

When pretraining with the biologically contingency-disadvantaged (hereafter referred to as *contingency-disadvantaged*) stimulus element preceded compound-stimulus training, Schindler and Weiss' (1985) stimulus–element tests revealed (a) predominantly tone control in their food group and (b) predominantly light control in their avoidance group.

---

This research was supported by NIMH Research Grant MH-45545 and NIDA Research Grant DA-08651. It was presented at the 1998 Winter Conference on Animal Learning and Behavior in Winter Park, Colorado.

Reprints may be requested from Stanley J. Weiss, Department of Psychology, American University, Washington, D.C. 20016 (E-mail: sweiss@american.edu).

The biological constraint on learning (i.e., the stimulus-reinforcer interaction) in rats was surmounted by pretraining with the contingency-disadvantaged element, even after 15 sessions of compound-stimulus training lasting 2 to 4 hr each.

Although Schindler and Weiss (1985) were able to block this selective association in rats, LoLordo, Jacobs, and Foree (1982) were not able to block it in pigeons. Despite pretraining with the contingency-disadvantaged element, food training produced visual control and shock-avoidance training produced auditory control in LoLordo et al.'s pigeons. Such an inconsistency in outcomes has important implications for this biological constraint on learning, suggesting species differences that limit the generality of the constraint. However, the possibility remains that these disparate results are due to procedural differences between the experiments of Schindler and Weiss and LoLordo et al., rather than to inherent differences between rats and pigeons.

As a first step in resolving whether the conflicting results of Schindler and Weiss (1985) and LoLordo et al. (1982) represent a true species difference, the procedures that successfully blocked the selective association in rats should be systematically replicated (Sidman, 1960) with pigeons. As yet, a stimulus-reinforcer interaction has not been reported for pigeons following compound-stimulus training with multiple schedules of the type employed by Schindler and Weiss (1982, 1985) with rats. (Foree & LoLordo, 1973, and LoLordo et al., 1982, used discrete-trials training with their pigeons.)

Prior to attempting to block a selective association in pigeons through pretraining with procedures that blocked this type of association in rats (Schindler & Weiss, 1985), it was necessary to determine whether a selective association would be obtained in pigeons given (a) compound  $S^D$  discrimination training with the multiple schedules used by Schindler and Weiss (1982, 1985) with rats and (b) stimulus parameters that emulated those used by LoLordo et al. (1982) with pigeons. Therefore, in Experiment 1 two groups of pigeons were trained with multiple schedules. A compound stimulus (TL) was used as the  $S^D$  from the start of training, with one group earning food and one group avoiding shock in TL. In

the absence of TL, food and shock were not presented (extinction). After this training, the pigeons were given a stimulus-element test to determine whether stimulus control was predominantly visual or auditory. These groups were also meant to serve as compound-only controls for the pigeons in Experiment 2, which were pretrained with the contingency-disadvantaged stimulus element prior to compound-stimulus training.

## EXPERIMENT 1: COMPOUND-ONLY TRAINING

### METHOD

#### *Subjects*

Six naive homing pigeons (approximately 4 months old) and 2 naive White Carneau pigeons (approximately 2 years old) were individually housed under a 12:12 hr light/dark cycle (lights on at 8:00 a.m.). Birds in both groups (food and shock avoidance) were maintained at approximately 80% of their free-feeding weights.

Birds trained with shock-avoidance schedules were implanted with stainless steel electrodes (orthodontic wire) around the pubis bones under aseptic conditions using the method of Azrin (1959). The pubis bones are close to the surface, and the implantation procedure is essentially equivalent to a subcutaneous injection with a hypodermic needle. Pigeons were fitted with ultrasuede jackets, and the electrode wires were connected to a female RCA phono jack that exited at the back of the jacket.

#### *Apparatus*

Two operant chambers were enclosed in sound-attenuation chests (Weiss, 1970). Internally, each chamber measured 36 cm long, 24 cm wide, and 26 cm high. The side and rear walls were translucent white acrylic. The front wall was unblemished smooth aluminum painted white with no protrusions or irregularities. The ceiling was clear acrylic with 1.3 cm ventilation holes spaced approximately 2.5 cm apart. The chambers had stainless steel grid floors with a 1.3-cm solid aluminum border.

A plastic treadle manipulandum (9 cm by 5.5 cm) was attached to a rod inserted

through a hole in the front wall 2.5 cm from the floor and 2.5 cm from the left wall. The treadle was tilted down from the wall, with the front edge 1.5 cm above the floor and the rear edge 3.5 cm above the floor. A response on the treadle with a minimum force of about 0.146 N (15 g) was required to close a micro-switch. A food aperture (5.8 cm by 5 cm) was located on the front wall to the right of the treadle, centered 2.5 cm above the floor and 2.5 cm from the right wall. Activating a solenoid raised a hopper filled with mixed-grain pigeon feed (Purina ProGrains) to the lower edge of the aperture. No hopper light was used.

A white 15-W houselight and a red 60-W stimulus light (both 120 volts) were situated behind the right translucent wall. Whenever the red light was on, the white light was off, and vice versa. A 400-Hz tone with an intensity of approximately 80 dB was produced by a Hewlett-Packard wide-range oscillator (Model 200CD) and was delivered through a 5.25-in. Realistic speaker mounted in an enclosure 3 cm behind the right wall of the chamber next to the lights. Ambient noise was measured at approximately 68 dB with the exhaust fan on. Auditory stimuli were measured by a General Radio 1565-A SPL meter, scale C. The microphone was perpendicular to the front wall of the chamber, approximately 3 cm above the treadle and 3 cm from the left wall.

Two solid-state shockers were used (BRS Model SGS-003 and Coulbourn Model E13-16). One was dedicated to each chamber. The shock from only one pair of leads from the set of scrambled outputs was delivered to a female ¼-in. phono jack mounted in the center of the chamber's ceiling. A cable with a male ¼-in. phono jack on each end connected the ceiling jack with the RCA connector attached to the pigeon's jacket. Because the phono plug could rotate in the ceiling jack, the shock cable did not restrain the bird's movement.

Experimental events were controlled and recorded by a computer located in an adjacent room through a MED Associates interface. Training sessions for all groups were conducted 6 days per week.

#### *Compound-Only Trained Food Group*

On the 1st day of training, pigeons were simply placed in the chambers for 3 hr of ha-

bituation with the white light on and food scattered on the aluminum strip bordering the floor. Hopper training began on the 2nd day, with TL (tone and red light) on throughout the session. The hopper was raised for 15 s every 2 to 3 min, and when the pigeon depressed the treadle. When the hopper was being raised, the solenoid activation and the grain tray hitting the base of the food aperture were audible. On the next day, with TL on throughout the session, responding was reinforced on a variable-interval (VI) 7.5-s schedule. During this session and for the remainder of the experiment, the hopper duration was 4.5 s. Over the next 12 to 15 sessions, the VI value was increased to 15, 30, 45, and finally 60 s, with TL presented throughout each session. Sessions lasted until approximately 50 reinforcers had been delivered.

After 4 days of VI 60-s training, a multiple schedule was instituted wherein treadle responses were reinforced in TL. When TL was off and the white light was on, responding did not produce food (extinction). TL and TL-off schedule components alternated on the average of once per minute within the range of 30 to 120 s ( $SEM = 5.2$ ) for TL and 40 to 90 s ( $SEM = 4$ ) for TL-off. To reduce response rates in the extinction component, when the pigeon responded within the last 5 s of TL-off, TL presentation was delayed until 5 s had passed without a response. The value of the response correction was increased from 5 to 10 s for all pigeons. The response correction was increased to 20 s for H-6 after it failed to meet criterion in close to double the number of sessions the other birds required. Sessions averaged 1 hr in length and ranged from 40 to 90 min depending upon how often the response correction was activated.

*Discrimination criteria.* Training under the multiple VI 60-s extinction schedule was continued until a pigeon's response rate in TL was at least nine times greater than the rate in TL-off for three consecutive sessions.

*Stimulus-element test.* Preceding the test, the baseline schedule was in effect for approximately 45 min as a warm-up, which counted as the third criterion baseline session. Once the test began, no food was given for the rest of the session. During the test, tone, red light, and the TL compound were each presented

Table 1

Training data for each compound-only trained pigeon in Experiment 1 during criterion baseline sessions. Number of discrimination sessions prior to testing, responses per minute in the presence of tone plus light (TL) and the absence of TL, as well as shocks per minute and reinforcers per minute, are included.

	Shock avoidance						Food				
	H1	H7	C1	C2	M		H3	H4	H5	H6	M
Discrimination sessions	11	7	16	17	12.8	Discrimination sessions	10	6	10	25	12.8
TL	19.6	16.6	23.5	21.5	20.3	TL	14.6	34.7	17.5	18.6	21.4
Absence	1.9	1.8	2.7	2.7	2.3	Absence	0.7	2.0	1.1	2.0	1.5
Shocks	0.50	0.24	0.01	0.04	0.20	Reinforcers	0.75	0.72	0.80	0.70	0.74

24 times for 60 s each in a block-randomized order wherein no stimulus followed itself. Between test-stimulus presentations, for 60 s the tone and red light were off while the white light was on. During each condition, treadle responses were recorded. The test lasted 144 min.

#### *Compound-Only Shock-Avoidance Group*

One 3-hr session of habituation in the chamber was given with only the white light on. During the next session, escape training was conducted with TL (tone and red light) present. Termination of a pulsed shock was used to successively approximate treadle responding. This occurred very rapidly (within 5 to 10 min). A free-operant avoidance (FOA) schedule was then instituted during the same session wherein each response reset a 25-s timer (response–shock [R-S] interval = 25). When 25 s passed without a response, shock was presented every 5 s (shock–shock [S-S] interval = 5) until a response was emitted. Under FOA each shock lasted 0.5 s, with a response during shock resetting the shock duration timer such that the shock never terminated within 0.5 s of a response. This was instituted to reduce shock-elicited or occasioned treadle presses.

This FOA schedule was maintained during daily training sessions (approximately 2 hr long) with TL on continuously. Shock intensity was adjusted to be no higher than necessary to maintain responding (0.4 to 0.8 mA). This TL-only training continued until a pigeon avoided 75% of the potential R-S scheduled shocks (i.e., received 0.6 shocks per minute or less) for five consecutive sessions. This required 15 to 25 sessions. Then, a multiple schedule was instituted wherein

the FOA schedule was in effect during TL, but no shock was programmed (extinction) in the absence of TL. When TL commenced, the R-S interval was in effect. Thus, the pigeon had to treadle press within 25 s of TL onset to avoid the first potential shock in a TL component. Responses during the extinction component did not prolong that component, as they did for the food group. The TL components averaged 125 s within a range of 60 to 200 s ( $SEM = 7.1$ ), and TL-off schedule components averaged 176 s within a range of 87 to 280 s ( $SEM = 9.9$ ). Training sessions under this two-component multiple schedule lasted an average of 1.9 hr ( $SEM = 0.2$  hr).

*Discrimination criteria.* A pigeon was trained under the multiple FOA extinction schedule until (a) its response rate in the FOA component (TL) was at least nine times that in the extinction component (white light) for 3 consecutive days, (b) it was avoiding at least 75% of the potential R-S 25-s shocks, as described above, and (c) it commenced treadle pressing, prior to a shock prompt, in at least 75% of the TL components. (Pigeons C1 and C2 were tested with discrimination response ratios of 8.7 and 8.0, respectively, when they reached 1.5 to 2 times the training sessions of the other pigeons in the group.) After satisfying these criteria, each pigeon received a stimulus-element test identical to that administered to the compound-only food group.

## RESULTS AND DISCUSSION

Terminal baseline response and reinforcement rates, as well as discrimination training sessions to criterion, are presented in Table 1. The treadle pressing of all pigeons was clearly under stimulus control, with mean TL

Table 2

Stimulus-element test results for compound-only trained pigeons in Experiment 1. Response rates in the presence of tone, red light, and tone-plus-light (TL) and in the absence of TL are indicated for each bird.

	Shock avoidance					Food				
	H1	H7	C1	C2	M	H3	H4	H5	H6	M
Tone	7.6	2.2	22.2	9.5	10.4	0.5	0.0	0.5	0.5	0.4
Red light	0.4	0.8	10.5	5.7	4.3	8.9	15.5	4.6	5.8	8.7
TL	8.5	3.8	24.0	21.6	14.5	7.7	21.9	10.9	7.5	12.0
Absence	1.2	1.6	6.1	4.8	3.4	0.7	0.4	0.3	0.8	0.6

rates differing by only 1.1 responses per minute over groups. Rates in TL absence were minimal.

Stimulus-element test results for each subject are presented in Table 2. This test assayed the degree of control by each of the elements comprising the compound  $S^D$ , tone and red light. All food-trained pigeons emitted over 90% of their element responses in the red light. In comparison, light controlled only 25% of the element responses in the shock-trained pigeons, a significantly lower percentage,  $t(6) = 9.29$ ,  $p < .01$ . A Stimulus-Element  $\times$  Group ANOVA yielded a significant interaction,  $F(1, 6) = 18.11$ ,  $p < .01$ . Paired comparisons using contrasts confirmed that the food group emitted significantly more responses to light than to tone,  $F(1, 6) = 12.18$ ,  $p < .02$ , and the shock-avoidance group emitted significantly more responses to tone than to light,  $F(1, 6) = 6.40$ ,  $p < .05$ . This significant interaction demonstrates that the stimulus parameters used here were capable of producing a stimulus-reinforcer interaction (see Figure 1) similar to that reported by Forre and LoLordo (1973) in pigeons given discrete-trials training. This represents the first demonstration of a selective association in pigeons trained on free-operant multiple schedules of reinforcement.

When Schindler and Weiss (1982) reported a selective association in rats trained on multiple schedules like those used with pigeons in this experiment, they also found a configural effect wherein the compound controlled a higher rate in testing than either element did. Table 2 reveals that was also true for the pigeons in Experiment 1. Overall TL controlled rates 1.4 times higher than those controlled by the high-rate element for the shock-avoidance group (tone) and the food

group (light). The test rate to TL was significantly higher than that controlled by the high-rate element,  $t(7) = 2.45$ ,  $p < .05$ .

## EXPERIMENT 2: ELEMENT PRETRAINING

We are now prepared to investigate whether the stimulus-reinforcer interaction produced in Experiment 1 can be blocked. In Experiment 2, multiple-schedule pretraining procedures like those employed by Schindler and Weiss (1985) with rats were used with pigeons. Pigeons now received discrimination training with the contingency-disadvantaged element of the compound prior to compound-stimulus discrimination training. Thus, the food group was pretrained on a multiple VI extinction schedule in which the VI  $S^D$  was a tone and extinction was signaled by tone-off. The avoidance group was pretrained on a multiple FOA extinction schedule in which the FOA  $S^D$  was a red light and extinction was signaled by red light-off. After the tone-food or light-shock discrimination was established, training was continued for 15 additional sessions with the  $S^D$  changed to TL (tone and red light). Then, a stimulus-element test was administered wherein tone, red light, and TL were presented.

Schindler and Weiss' (1985) rats showed control by the pretrained element in testing. However, technically, similar test rates to tone and light would also indicate that pretraining blocked the selective association. Control by the pretrained stimulus is evidence that the selective association was completely surmounted by an associative process in rats. The modality of control was actually reversed! Would this also occur in pigeons, a species whose dominant sensory modality differs



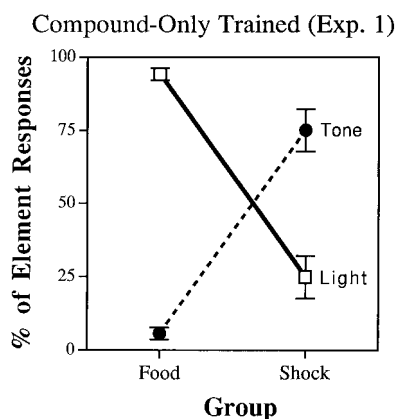


Fig. 1. Interaction profile showing results of the stimulus-element test for pigeons given compound-only training (Experiment 1). The mean percentages ( $\pm$  SEM) of responses in the presence of the tone (filled circles) and light (open squares) are shown for groups trained with food or with shock. To calculate these mean percentages, each pigeon's test responses in the presence of the tone and in the presence of the light were converted to a percentage of that pigeon's total responses in tone and in light. These results represent a systematic replication of the stimulus-reinforcer interaction with pigeons trained on multiple schedules of reinforcement.

from that of rats? A complete systematic replication of Schindler and Weiss' (1985) results in pigeons would demonstrate compelling cross-species generality in the associative processes that are responsible for blocking selective associations.

#### METHOD

##### *Subjects and Apparatus*

Eight naive homing pigeons comparable to those used in Experiment 1 were prepared and housed as described therein. The same apparatus was used in Experiments 1 and 2.

##### *Element-Pretrained Food Group*

On the 1st day of training, the pigeons were simply placed in the chambers for 3 hr of habituation with the white light on and food scattered on the aluminum border around the floor. Hopper training, VI training, and initial discrimination training were like that described for the compound-only food group of Experiment 1, with the exception that tone alone was presented rather than the TL compound.

During element discrimination training (i.e., pretraining), tone-on and tone-off

schedule components alternated as compound-on and compound-off did in Experiment 1. To reduce response rates in the extinction component (tone-off), when the pigeon responded within the last 5 s scheduled for the tone-off component, tone presentation was delayed until 5 s had passed without a response. Because of persistent responding in the absence of tone, to achieve auditory stimulus control with food it was necessary to increase the value of the response correction from 10 to 15, 20, 30, 40, and finally 60 s over the next 24 to 30 sessions. Sessions averaged 2 hr in length and ranged from 70 to 360 min depending upon how often the response correction was activated.

*Discrimination criteria.* Training under the multiple VI 60-s extinction schedule was maintained until a pigeon's response rate in the presence of the tone was at least nine times greater than during tone-off for five consecutive sessions. Once this discrimination criterion was met, compound-stimulus training began. The same multiple schedule was used, with response correction described above, but now tone and red light (TL) were presented simultaneously during the VI 60-s component. After 15 sessions of discrimination training averaging 2-hr each (range, 80 to 220 min) with the compound stimulus, a stimulus-element test like that described in Experiment 1 was administered. Programmed component durations (not including time added by response correction) for element and compound discrimination training of this food group were the same as those used with the food group of Experiment 1.

##### *Element-Pretrained Shock-Avoidance Group*

Habituation, shock escape, and FOA training were implemented as described for the compound-only avoidance group of Experiment 1, but the element-pretrained avoidance group was in red light rather than the TL compound.

The FOA schedule was maintained during daily training sessions (approximately 3 hr), with the red light present throughout each session, until a pigeon avoided 75% of the potential R-S scheduled shocks for five consecutive sessions. This required 8 to 16 sessions. Then, a multiple schedule was instituted wherein the FOA schedule was in effect in

Table 3

Training data for each element-pretrained pigeon in Experiment 2 during criterion baseline sessions of element pretraining and the last three sessions of compound training. Number of discrimination sessions, responses per minute in light, tone, tone plus light (TL) and the absence of these respective stimuli, as well as shocks per minute and reinforcers per minute, are included.

Shock avoidance						Food					
	H17	H18	H19	H20	<i>M</i>		H21	H22	H23	H24	<i>M</i>
<hr/>											
Element pretraining											
Discrimination sessions	60	26	67	51	51.0	Discrimination sessions	96	35	45	55	57.8
Light	24.1	10.8	22.2	19.4	19.1	Tone	26.3	36.0	21.2	17.0	25.1
Absence	1.5	1.1	1.4	2.0	1.5	Absence	2.4	2.4	1.8	1.3	2.0
Shocks	0.22	0.18	0.02	0.02	0.11	Reinforcers	0.75	0.85	0.75	0.74	0.77
<hr/>											
Compound training											
Discrimination sessions	15	15	15	15	15.0	Discrimination sessions	15	15	15	15	15.0
TL	24.2	11.7	25.1	23.5	21.1	TL	31.9	43.0	14.8	16.7	26.6
Absence	1.2	1.5	1.8	3.8	2.1	Absence	0.7	1.5	1.0	0.7	1.0
Shocks	0.06	0.24	0.01	0.02	0.08	Reinforcers	0.77	0.80	0.64	0.70	0.73

the presence of the red light, but no shock was programmed (extinction) when the red light terminated and the white light came on. Responses in the extinction component did not prolong that component, as they did in the food group. The FOA and extinction components alternated as they did in Experiment 1.

*Discrimination criteria.* A pigeon was trained under the multiple FOA extinction schedule specified above until its performance satisfied the discrimination criteria described for the compound-only avoidance group in Experiment 1. These sessions averaged 3.3 hr ( $SEM = 0.1$  hr). Then, compound-stimulus training was begun. The same multiple schedule was maintained, but now the red light and tone were presented simultaneously during FOA components. After 15 daily compound-stimulus discrimination training sessions averaging 3.1 hr ( $SEM = 0.2$  hr), these pigeons received a stimulus-element test identical to that administered to the pretrained food group. Component durations for element and compound discrimination training of this shock group were the same as those used with the shock group of Experiment 1.

## RESULTS AND DISCUSSION

### Training

Criterion data are presented in Table 3 for the element-pretraining phase of Experiment

2 and the subsequent compound-stimulus training phase. Terminal baseline response and reinforcement rates, as well as discrimination training sessions to criterion, are also presented. The treadle pressing of each pigeon was clearly under control of the stimulus element at the end of pretraining. There was no systematic change in rates when the contingency-advantaged element was added to the pretrained element, creating the TL compound. This is revealed when pretrained element criterion rates from Table 3 (A) are compared to TL rates for the initial three compound training sessions (B). For shock-trained Birds 17, 18, 19, and 20, these rates (A/B) were, respectively, 24.1/25.1, 10.8/10.7, 22.2/20.6, and 19.4/23.5. These A/B rates were 26.3/24.6, 36.0/26.1, 21.2/24.2, and 17.0/9.5 for food-trained Birds 21, 22, 23, and 24, respectively. Rates in TL absence were essentially unchanged during this transition.

Response rates in TL after 15 sessions of compound-stimulus discrimination training were, overall, within 10% of those controlled by the pretrained element in the previous phase. Criterion TL rates were similar across groups in Experiment 2,  $t(6) = 0.74$ ,  $p > .48$ , just as they were in Experiment 1. Furthermore, criterion TL rates were comparable for the four groups of Experiments 1 and 2,  $F(3, 12) = 0.43$ ,  $p > .74$ .

Table 4

Stimulus-element test results for element-pretrained pigeons in Experiment 2. Response rates in the presence of tone, red light, and tone-plus-light (TL) and in the absence of TL are indicated for each bird.

	Shock avoidance					Food				
	H17	H18	H19	H20	M	H21	H22	H23	H24	M
Tone	3.7	0.7	1.0	2.2	1.9	11.9	15.5	5.8	3.0	9.0
Red light	27.1	9.3	10.0	22.0	17.1	11.2	6.3	1.5	1.3	5.1
TL	28.5	11.7	13.6	21.7	18.9	20.1	31.9	11.3	13.6	19.2
Absence	2.5	2.2	2.9	5.5	3.3	1.1	0.6	1.1	0.3	0.8

In Experiment 1, in which pigeons received only compound-stimulus discrimination training, the discrimination criteria were satisfied after an average of 12.8 sessions for both food and shock-avoidance groups. In comparison, about four times as many sessions were required to reach these criteria in the element-pretraining phase of Experiment 2. Two factors probably contributed to the more rapid acquisition by compound-only than element-pretrained pigeons in the present study. First, discrimination training is more effective with multielement cues than with single-element cues (Eninger, 1952; Estes, 1950; Kamin, 1969). Second, acquisition is two to three times faster when the contingency-advantaged stimulus is the  $S^D$  than when the contingency-disadvantaged stimulus is the  $S^D$  (LoLordo et al., 1982, Experiment 1).

#### *Stimulus-Element Test*

Experiment 2 stimulus-element test results are presented in Table 4. When compound-stimulus training followed element pretraining, 68.1% of the element test responses of food-trained pigeons were emitted in the tone (their pretrained stimulus). In comparison, 90.7% of the element test responses of the shock-avoidance trained pigeons were emitted in the light (their pretrained stimulus). The percentage of element responses controlled by the light was significantly greater in the shock group (90.7%) than in the food group (31.9%),  $t(6) = -9.80$ ,  $p < .01$ . This stimulus control is the reverse of that obtained in Experiment 1.

A Stimulus-Element  $\times$  Group ANOVA yielded a significant interaction,  $F(1, 6) = 20.71$ ,  $p < .01$ . Paired comparisons using contrasts showed that the shock-avoidance

group emitted significantly more responses to light than to tone,  $F(1, 6) = 25.98$ ,  $p < .01$ . Although the difference between tone and light failed to reach significance in the food group,  $F(1, 6) = 1.79$ ,  $p > .22$ , all pigeons in the food group had higher rates in the presence of the tone than in the presence of the light, and overall tone rate was almost double that in the presence of the light for this group. This clearly shows that the selective association was blocked in the pretrained food group, because the compound-only trained food group of Experiment 1 emitted, on average, close to 22 times more responses in the presence of the light than in the presence of the tone.

The Experiment 2 interaction profile presented in Figure 2 (after element pretraining) is the mirror image of that presented in Figure 1, in which pigeons received only compound-stimulus discrimination training. This shows, contrary to previous findings (LoLordo et al., 1982), that a stimulus-reinforcer interaction can be powerfully blocked in pigeons, just as it was blocked in rats (Schindler & Weiss, 1985). Associative processes have again been shown to have a profound influence on a phenomenon classified as a biological constraint on learning (cf. Panlilio & Weiss, 1993; Weiss, Panlilio & Schindler, 1993a, 1993b).

In Experiment 1, during testing the compound controlled approximately 1.4 times the high-rate element in both the food and the shock-avoidance trained pigeons. This configural effect was obtained in only the food group in Experiment 2 for whom TL controlled significantly more (double) responding than the high-rate element did,  $t(3) = 4.59$ ,  $p < .02$ . In comparison, for the pretrained shock pigeons TL and the high-rate



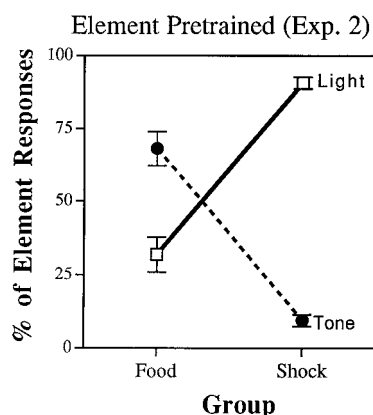


Fig. 2. Interaction profile showing results of the stimulus-element test for pigeons pretrained with the biologically contingency-disadvantaged element prior to compound-stimulus training (Experiment 2). The mean percentages ( $\pm$  SEM) of responses in the presence of the tone (filled circles) and light (open squares) are shown for groups trained with food or with shock. To calculate these mean percentages, each pigeon's test responses in the presence of the tone and in the presence of the light were converted to a percentage of that pigeon's total responses during tone and during light. The pretrained stimulus was dominant in each group, demonstrating that the stimulus-reinforcer interaction was powerfully blocked.

element controlled similar rates of treadle pressing in testing, 18.9 and 17.1 responses per minute, respectively. This difference in configural effects for pretrained food and shock groups, as well as the asymmetry of the Figure 2 interaction profile, suggests that blocking was more complete in the pretrained shock pigeons than in the pretrained food pigeons.

In the pretrained pigeons, that the added visual element would gain more control with food than the added auditory element would with shock is consistent with the stronger selective association obtained with food than with shock (see Figure 1) for the compound-only trained pigeons of Experiment 1. In Experiment 1, light controlled 94.3% of the element responses for the food group, whereas tone controlled a significantly smaller 75.1% of the element responses for the shock group,  $t(6) = 2.57$ ,  $p < .05$ . Similar relative selective association effects for food and shock groups have been reported in rats (Schindler & Weiss, 1982) and pigeons (Foree & LoLordo, 1973).

In experiments investigating blocking in the classical conditioning paradigm, unconditioned stimulus-only and truly random conditioned stimulus/unconditioned stimulus controls are often used. Unfortunately, these controls cannot be effectively applied in the operant situation because their underlying operations often interfere with, and even counteract, the behavioral control derived from stimulus-response-reinforcer contingencies. For example, applying the truly random control procedure to the conditioned emotional response paradigm caused rats to cease bar pressing, and they did not recover (Seligman, 1968). The compound-only trained pigeons of Experiment 1 in the present study are the controls for Experiment 2. They reveal the stimulus control resulting without pretraining to the contingency-disadvantaged element of the compound. The extensive pretraining to a stringent discrimination criterion had the predicted effect, completely reversing the compound-only training interaction profile (cf. Figures 1 and 2). Therefore, plausible alternative explanations of this dramatic outcome are essentially eliminated (Seligman, 1969).

## GENERAL DISCUSSION

In Experiment 1, the stimulus-reinforcer interaction produced in pigeons with discrete-trials training (Foree & LoLordo 1973; LoLordo et al., 1982) was systematically replicated for the first time using free-operant multiple schedules of reinforcement with this species. After establishing that our multiple-schedule training procedures and stimulus values produced a robust stimulus-reinforcer interaction with compound-only discrimination training (see Figure 1), we progressed to Experiment 2.

### *Comparison of Schindler and Weiss (1985) and Experiment 2*

Experiment 2 was designed to be methodologically comparable to that of Schindler and Weiss (1985), who blocked a stimulus-reinforcer interaction in rats. In Experiment 2, pretraining pigeons with the contingency-disadvantaged stimulus element did more than minimally block acquisition of predominant control by the added reinforcer-advan-

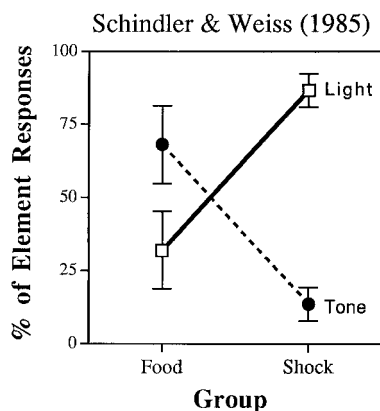


Fig. 3. Interaction profile showing results of the stimulus-element test for rats pretrained with the biologically contingency-disadvantaged element prior to compound-stimulus training, as the pigeons in Experiment 2 of the present study were. The mean percentages ( $\pm$ SEM) of responses in the presence of the tone (filled circles) and light (open squares) are shown for groups trained with food or with shock. To calculate these mean percentages, each rat's test responses during tone and during light were converted to a percentage of that rat's total responses during tone and during light. (Figure derived from data presented in Schindler & Weiss, 1985.)

tagged element during subsequent compound-stimulus training. Control by the pretrained element was maintained after extensive compound-stimulus training, just as it was in Schindler and Weiss' (1985) rats.

The interaction profile produced by Schindler and Weiss' (1985) pretrained rats presented in Figure 3 bears a striking resemblance to that produced by the pretrained pigeons in Experiment 2 of the present study (see Figure 2). This comparability over species is especially noteworthy, and not entirely anticipated, because rats and pigeons have different dominant sensory modalities. Establishing species generality is an important type of scientific advance because "When one technique is shown to be applicable to several species, we gain additional confidence for related techniques [and processes]" (Sidman, 1960, p. 66).

#### *Comparison of LoLordo et al. (1982) and Experiment 2*

Although the stimulus-reinforcer interaction was blocked in Experiment 2 of the present study, but not by LoLordo et al. (1982), there are several areas of agreement between

these studies that should not be overlooked. For example, LoLordo et al.'s pigeons that earned food (Experiment 2) or avoided shock (Experiment 3) *only* in the TL compound produced a stimulus-reinforcer interaction qualitatively similar to that reported for the compound-only trained pigeons in Experiment 1 of the current study. Furthermore, although LoLordo et al.'s pretraining (tone-food or light-shock) did not block the stimulus-reinforcer interaction in their pigeons, it did have a measurable influence on its magnitude. In testing, their pretrained groups responded more in the presence of the pretrained (i.e., the contingency-disadvantaged) element than did their compound-only trained pigeons. This pattern of results suggests, as one might expect, that pretraining can produce a continuum of effects, from a modest increase in control by the pretrained element (LoLordo et al.) to predominant control by that stimulus (Experiment 2, present study).

LoLordo et al.'s (1982) procedures included many response-correlated and reinforcer-correlated stimulus changes that were unrelated to, and could even have conflicted with, the stimulus-reinforcer associations that were the objective of their pretraining, tone-food and light-shock. They employed discrete-trials training wherein a pigeon's first treadle press in the 5-s stimulus produced 5-s access to an illuminated grain-filled magazine (food group) or avoided shock (shock group) while simultaneously terminating the stimulus. Thus, in their pretrained food group, tone control might have been compromised when tone offset *and* a hopper-light onset signaled grain. In addition, intertrial interval responses darkened the chamber briefly (160 ms) for all pigeons. This variety of stimulus changes potentially created "noise" that could have contaminated their intended pretrained element associations.

In contrast, Schindler and Weiss' (1985) design, and that of the present Experiment 2, were intended to minimize response-correlated and reinforcer-correlated stimulus changes unrelated to their central pretraining stimulus-reinforcer contingencies, tone-food and light-shock. Neither responses nor the presentation of reinforcers was correlated with a change in the S<sup>D</sup>s setting the occasion for responding, and responses did not alter

the background illumination signaling the extinction period. This was accomplished with multiple schedules in which components were 1 to 3 min long, moderate steady response rates were maintained and responses did not terminate the  $S^D$ . Further, reinforcers were intermittent (VI food or FOA of shock), several could be earned per component, and they were seldom, if ever, correlated with component termination. In addition, rats (Schindler & Weiss, 1985) and pigeons (Experiment 2, present study) that were pre-trained to earn food in the presence of the tone had only an auditory magazine signal (i.e., sounds related to solenoid activation) associated with food presentation. Balsam and Gibbon (1988) have shown that the presence of an auditory stimulus during grain presentation facilitates tone-food associations in pigeons.

After pretraining, the pigeons in the present Experiment 2 and Schindler and Weiss' (1985) rats received 15 compound-stimulus training days wherein they earned reinforcers in TL for 30 to 45 hr. LoLordo et al.'s (1982) pigeons received five sessions of compound-stimulus training wherein they accumulated about 750 TL-food or TL-shock avoidance trials during which they were in the presence of TL for a total of up to an hour, and this was clearly enough for the added stimulus to gain control. In contrast, for the pigeons of the present Experiment 2, control was maintained by the pretrained stimuli even though they had appreciably more compound-stimulus time than LoLordo et al.'s (1982) pigeons, suggesting that little associative strength remained to be conditioned after pretraining in the pigeons in the present experiment (Rescorla & Wagner, 1972).<sup>1</sup>

<sup>1</sup> LoLordo et al. (1982) do not report the number of pretraining sessions for their tone-food (Experiment 2) or light-shock avoidance (Experiment 3) pretrained pigeons. However, in Experiment 1 they trained pigeons to criterion under these conditions, wherein the pigeons responded on at least 75% of the trials for one session. Extrapolating from their Experiment 1 groups, and including the five additional postcriterion sessions pigeons received in Phase 1 of Experiments 2 and 3, their pretrained food group should have received an average of 13.8 pretraining tone-food sessions, whereas their pretrained shock-avoidance pigeons should have received an average of 14 light-shock sessions.

In Experiment 2 of the present study, pretraining con-

To summarize, the procedures used in Experiment 2 of the present study differed from those of LoLordo et al. (1982) in many ways, including multiple-schedule versus discrete-trials discrimination training, many responses per  $S^D$  versus one response per  $S^D$ , partial reinforcement of responding in  $S^D$  versus 100% reinforcement,  $S^D$  extending beyond the occurrence of a response (even a reinforced one) versus a response terminating the  $S^D$  and producing reinforcement simultaneously, auditory only versus audiovisual grain-magazine signals, extinction versus reinforced testing, rate versus single response emission as dependent variables, potentially more versus less element pretraining, and more versus less compound-stimulus training. The number of procedural differences in these two experiments, plus the potential interactions between these factors, make determination of the precise causes of the conflicting results in these pretraining experiments a potentially overwhelming undertaking, although some recommendations have been proposed above. In any event, that undertaking is clearly beyond the objective of the current experiments, which demonstrated that selective associations can be blocked in pigeons when the procedures effective with rats are systematically replicated.

### Conclusion

One of the problems Domjan and Galef (1983) found with the constraints on learning literature concerned its emphasis on cataloguing phenomena apparently inconsistent with the equipotentiality assumption of gen-

tinued until food pigeons achieved a 9:1 discrimination response ratio for five *consecutive* sessions and the shock-avoidance pigeons *additionally* met shock-rate criteria (see Procedure). To achieve this, in Experiment 2 of the present study food pigeons received an average of 57.8 pretraining sessions and the pretrained shock pigeons received an average of 51 sessions. Although a comparison between discrete-trials and multiple-schedule training sessions is at best indirect, it can be argued that the pigeons in Experiment 2 of the present study received more pretraining to more rigorous criteria than did those of LoLordo et al. (1982). Unfortunately, even if one accepts that comparison, its implications must be viewed cautiously because parametric manipulation of neither amount of element overtraining (Blumenthal, 1980) nor compound training (Azorlosa & Cicala, 1988) has produced powerful, systematic, or consistent effects on blocking.

eral-process learning theory, with species differences emphasized. They lamented that unifying testable explanatory concepts were seldom generated, and suggested that possibly one of the most important endeavors in the study of constraints on learning is a better understanding of species differences and similarities. The present experiments were formulated in that spirit. For the first time, a stimulus–reinforcer interaction has been blocked in pigeons. What has been interpreted until now as a species-based difference related to the selective-association constraint on learning can instead be attributed to procedural differences between the studies of Schindler and Weiss (1985) and LoLordo et al. (1982).

The equivalence of our results with pre-trained pigeons and those of Schindler and Weiss (1985) with rats pretrained under comparable conditions (cf. Figures 2 and 3) compellingly supports the operation of similar underlying processes across species. In addition, the fact that a stimulus–reinforcer interaction can be blocked in both species further illustrates how associative mechanisms can profoundly influence, and even override, a biological constraint on learning. The blocking phenomenon played a central role in the formulation of the influential Rescorla–Wagner (1972) model of associative learning. By demonstrating that the blocking of selective associations generalizes over species, the current study further relates this biological constraint on learning to general conditioning principles.

## REFERENCES

- Azorlosa, J. L., & Cicala, G. A. (1988). Increased conditioning in rats to a blocked CS after the first compound trial. *Bulletin of the Psychonomic Society*, 26, 254–257.
- Azrin, N. H. (1959). A technique for delivering shock to pigeons. *Journal of the Experimental Analysis of Behavior*, 2, 161–163.
- Balsam, P. D., & Gibbon, J. (1988). Formation of tone-US associations does not interfere with the formation of context-US associations in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, 14, 401–412.
- Blumenthal, A. C. (1980). The Kamin blocking effect as a function of length of pretraining. *Dissertation Abstracts International*, 42–02, Section B, 805.
- Domjan, M., & Galef, B. G. (1983). Biological constraints on instrumental and classical conditioning: Retrospect and prospect. *Animal Learning & Behavior*, 11, 151–161.
- Eninger, M. U. (1952). Habit summation in a selective learning problem. *Journal of Comparative and Psychological Psychology*, 45, 604–608.
- Estes, W. K. (1950). Toward a statistical theory of learning. *Psychological Review*, 57, 94–107.
- Force, D. D., & LoLordo, V. M. (1973). Attention in the pigeon: The differential effect of food getting vs. shock avoidance procedures. *Journal of Comparative and Physiological Psychology*, 85, 551–558.
- Kamin, L. J. (1969). Predictability, surprise, attention, and conditioning. In B. A. Campbell & R. M. Church (Eds.), *Punishment and aversive behavior* (pp. 279–296). New York: Appleton-Century-Crofts.
- LoLordo, V. M. (1979). Selective associations. In A. Dickinson & R. A. Boakes (Eds.), *Mechanisms of animal learning and motivation: A memorial volume to Jerzy Konorski* (pp. 367–398). Hillsdale, NJ: Erlbaum.
- LoLordo, V. M., Jacobs, W. J., & Force, D. D. (1982). Failure to block control by a relevant stimulus. *Animal Learning & Behavior*, 10, 183–193.
- Panlilio, L. V., & Weiss, S. J. (1993). Reversibility of single-incentive selective associations. *Journal of the Experimental Analysis of Behavior*, 60, 85–104.
- Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variation in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning: Vol. 2. Current research and theory* (pp. 64–98). New York: Appleton-Century-Crofts.
- Schindler, C. W., & Weiss, S. J. (1982). The influence of positive and negative reinforcement on selective attention in the rat. *Learning and Motivation*, 13, 304–323.
- Schindler, C. W., & Weiss, S. J. (1985). Modification of a stimulus–reinforcer interaction by blocking. *Behavioral Processes*, 11, 123–130.
- Seligman, M. E. P. (1968). Chronic fear produced by unpredictable shock. *Journal of Comparative and Physiological Psychology*, 66, 402–411.
- Seligman, M. E. P. (1969). Control group and conditioning: A comment on operationism. *Psychological Review*, 76, 484–491.
- Sidman, M. (1960). *Tactics of scientific research*. New York: Basic Books.
- Weiss, S. J. (1970). An effective and economical sound-attenuation chamber. *Journal of the Experimental Analysis of Behavior*, 13, 37–39.
- Weiss, S. J., Panlilio, L. V., & Schindler, C. W. (1993a). Selective associations produced solely with appetitive contingencies: The stimulus–reinforcer interaction revisited. *Journal of the Experimental Analysis of Behavior*, 59, 309–322.
- Weiss, S. J., Panlilio, L. V., & Schindler, C. W. (1993b). Single-incentive selective associations produced solely as a function of compound-stimulus conditioning context. *Journal of Experimental Psychology: Animal Behavior Processes*, 19, 284–294.

Received January 5, 1998

Final acceptance August 25, 1998